

# Proposal of Pavement Markings for Speed Reduction on Road Curves

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## ABSTRACT

Speeding can be considered as primary contributor to fatal crashes. In an attempt to reduce speeds on roadways, Road facilities like speed cameras, warning advisory speed signs and pavement markings for speed reduction have been used. Pavement markings are one of the methods to help road users to slow down at relatively low-cost. Also these might be proper perceptual techniques in a variety of driving condition such as roundabouts, work zones and curves.

However, each country has their own perceptual techniques, besides, pavement markings in Korea have been being installed without discretion. So it's needed to determine which patterns are effective to reduce a speeding.

The objective is to suggest some idea of the suitable pavement markings on the national highway curves for safety. For this, a study was carried out to examine the similar projects that had been done in abroad before as well as field work in Korea.

This paper proposed some perceptual techniques for speed reduction on the national highway curves. Further study is to conduct an experiment with various methods based on our previous research. This proposal will contribute toward safe road environment in the near future.

## 1. INTRODUCTION

### 1.1 BACKGROUND

Speeding has been long recognized as a major factor in severity of car accidents. Studies overseas and in Korea have identified speed as a factor in fatal road crashes.

In an attempt to reduce speeds on roadways, engineering methods as well as enforcement, education have assisted in reducing speeds at hazardous location. Several countermeasures that can be found in the Manual on Uniform Traffic Control Devices(MUTCD, 2001) like speed cameras, regulatory signs, warning signs and flagging control for speed reduction in engineering methods can be effective.



Figure 1. Conventional countermeasures to speeding (source: MUTCD)

However, speed cameras are very expensive. In addition, regulatory signs, warning signs and flagging control can be difficult to cover every possible high-risk location without enforcement.

On the other hand, pavement markings as a perceptual countermeasure have been used to reduce driver's speeds. Not only these techniques might be useful at lowering speeds in a variety of driving condition such as roundabouts, work zones and curves.

These perceptual techniques are needed to determine which patterns are effective to reduce a speeding. Pavement markings in Korea have been being installed without discretion. The objective is to suggest some idea of the effective methods of pavement markings on road curves.

## 1.2 RESEARCH GOALS

This goal is to apply several pavement markings conducted by foreign countries to this study as follows;

- Determine pavement marking treatments based on previous research
- Provide recommendation for suitable pavement marking use on national highway curves

## 2. LITERATURE REVIEW

### 2.1 REVIEWS FOR EFFECTIVENESS OF SPEED REDUCTION

A report written by Katz. B. J. (2004) proved the effectiveness of peripheral transverse lines treatment for speed reduction in several sites. Speed measures were taken to evaluate the effectiveness of the markings during three phases: 1) before installation; 2) shortly after the installation; and 3) six months after the installation to examine long-term effects at each site. The markings resulted in a decrease in overall vehicle speeds with total vehicles as well as specific classifications of vehicles.

Godley. S. T., Triggs. T. J., Fildes. B. N., Brown. L. (1999) evaluated the effectiveness of a representative range of Perceptual Countermeasures to speeding (PCMs) using the driving simulator at MUARC. Six experiments were conducted on the simulator, each involving 24 to 36 participants with full driving licenses. As a result, several of the PCMs evaluated were concluded to be effective at reducing travel speeds, including full lane width and peripheral transverse lines.

Drakopoulos. A., Vergou. G. (2003) showed that installation of chevron patterns on the test ramp appeared to result in large speed reductions, speeds were found to be lower in the “after” period during all hours on both weekdays and weekends. The large speed reductions were observed despite the fact that data for the after period were collected 20 months after the converging chevron pavement markings were installed.


Arnold. E. D., Lantz. K. E. (2007) proved that the transverse lines treatment was effective way to reduce speeds. Transverse lines were installed on a major, four-lane undivided highway in the town of Zuni, Virginia. Average speeds both decreased and increased after installation. The decreases were statistically significant and the decreases ranged from 3 to 10 mph.

## 2.2 REVIEW OF THE USE OF PERCEPTUAL COUNTERMEASURES BY EACH COUNTRY

Several perceptual countermeasures to reduce driver’s speeds in this study were reviewed. As a result, various perceptual techniques in foreign countries have been used respectively in several ways to reduce speeds. Basically, kinds of perceptual countermeasures are as follows.

Transverse Lines: A series of lines which are perpendicular to the path of travel and are placed across the road like rumble strips, are the most commonly used form of pavement markings in speed reduction. Transverse Lines have two kinds of patterns; a pattern with constant widths and constant spacing and a pattern with varying widths and varying distances to warn drivers of the upcoming zone.

Table 1. Summary of results for transverse lines

Country	Type	Summary
UK		<p>☐ Traffic Signs Manual(2003)</p> <ul style="list-style-type: none"> <li>• Markings are used in certain conditions on high speed approaches to roundabouts, or on the main carriageways. Not used in an attempt to reduce speeds at sharp bends or other hazards.</li> <li>• The marking consists of 90 yellow transverse bars on main carriageways, and 45 on slip roads. The bars are 600 mm wide, and are laid at right angles to the centre line of the carriageway.</li> </ul>

USA	<p>□ Arnold. E. D., Lantz. K. E.,(2007)</p> <ul style="list-style-type: none"> <li>• Markings are used on a major four-lane undivided highway.</li> <li>• The bars were 12 inches wide and were placed 1 foot off the edge line, skip centerline, and solid yellow centerline separating the east and westbound lanes. Lanes are approximately 10.5 feet through the section; thus, the bars are approximately 8.5 feet long.</li> </ul>
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These are the examples of some pictures about transverse lines which are used in UAS and Korea as seen in figure 2.

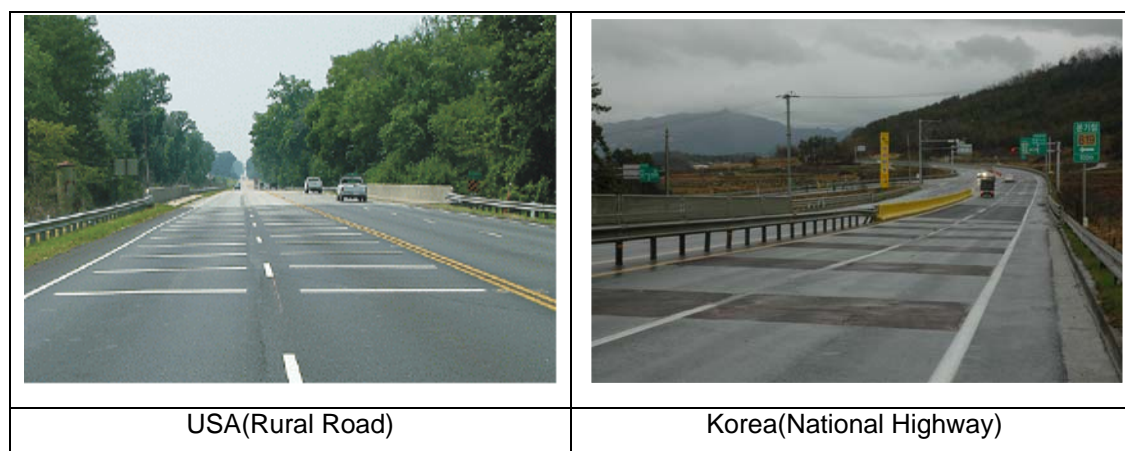





Figure 2. Examples of Transverse Lines on the roads

Peripheral Transverse Lines; A series of bars (typically white) which are perpendicular to the path of travel, Peripheral Transverse Lines have some kinds of patterns; a pattern with constant widths and constant spacing and a pattern with varying widths and varying ones.

Table 2. Summary of results for peripheral transverse lines

Country	Type	Summary
USA		<p>□ Katz. B. J. (2004)</p> <ul style="list-style-type: none"> <li>• Markings are used on two lane rural roadways.</li> <li>• The treatment as installed used 12 inch (30.5 cm) wide pavement markings extending 18 inches (45.7 cm) into the roadway spaced increasingly closer together and placed perpendicular to the travel lane on both the left and right edges of the travel lane.</li> </ul>

Australia		<p>❑ Macaulay. J.,(2004)</p> <ul style="list-style-type: none"> <li>• Markings are used in approaches to intersections on rural roadways. They're designed to encourage drivers to decelerate more rapidly.</li> <li>• Treatment starts approximately 435m from intersections, and goes over 400m (i.e., nothing over 35m immediately prior to intersections). Also, dimensions of peripheral transverse lines: 600mm wide, 600mm long, with a 4.5m gap between the parallel lines.</li> </ul>
UAS		<p>❑ Virginia Department of Transportation,(2002)</p> <ul style="list-style-type: none"> <li>• Local residential streets are eligible for traffic calming provided the posted speed limit does not exceed 25 mph; Two-lane roadways, Not a primary access to commercial or industrial sites.</li> <li>• Travel lanes not to be less than 9' in width.</li> </ul>

These are the examples of some pictures about peripheral transverse lines which are installed in USA and Australia as seen in figure 3.

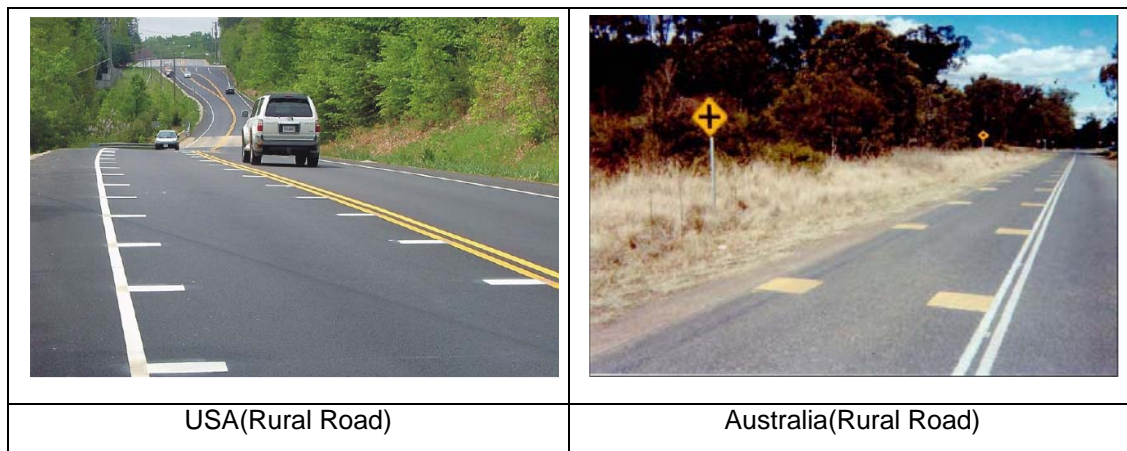




Figure 3. Examples of Peripheral Transverse Lines on the roads

Converging Chevron markings: a series of white chevrons which are painted on the road surface. The chevrons are placed increasingly close together as a driver moves into the pattern. The number of chevrons per set has to do with the speed within the pattern which usually ranged from 5 chevrons per set to 10.

Table 3. Summary of results for converging chevron markings

Country	Type	Summary
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Japan		<input type="checkbox"/> Hancock. K. L., Riessman. R., (2004) <input type="checkbox"/> Drakopoulos. A., Vergou. G., (2003) <ul style="list-style-type: none"> <li>• Markings are used on high-speed ramps.</li> <li>• Sets of 4 to 10 chevrons per set, all sets have chevrons of 15 cm each.</li> </ul>
USA		
UK		<input type="checkbox"/> Traffic Signs Manual(2003) <ul style="list-style-type: none"> <li>• The chevron markings are used on motorways only.</li> <li>• The marking is intended to remind drivers to keep a safe distance from the vehicle in front and has been shown to be beneficial in reducing accidents.</li> <li>• The start of a series of markings should be at least 1.6 km from the end of a previous entry slip road and should terminate at least 3.2 km before the next slip road.</li> </ul>

These are the examples of some pictures about converging transverse lines which are installed in UAS and Japan as seen in figure 4.

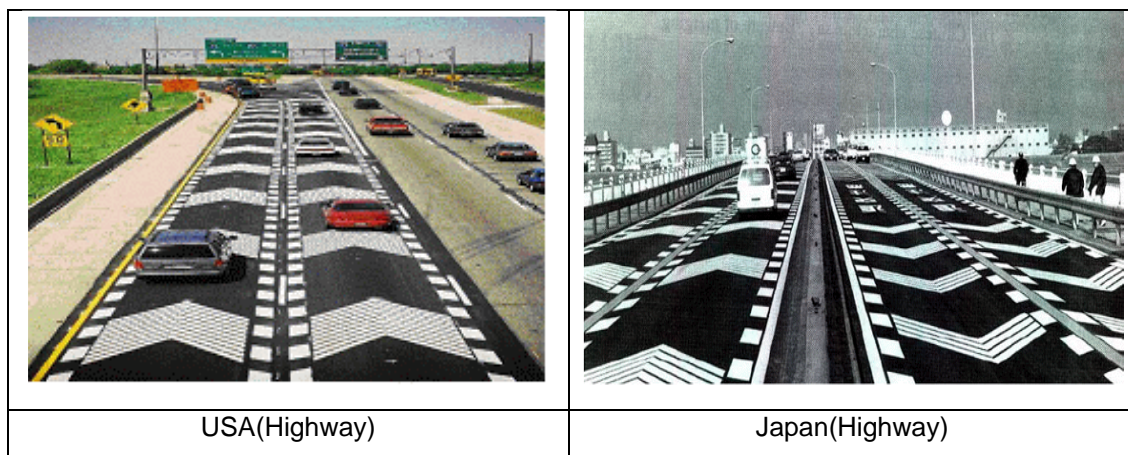



Figure 4. Examples of converging chevron markings on the roads

Drenthe Province PCM: PCM treatment that will be referred to as the Drenthe Province PCM. It was formulated in the Netherlands by the TNO research organization and the University of Groningen.

Table 4. Summary of result for Drenthe Province PCM

Country	Type	Summary
Netherlands		<input type="checkbox"/> Godley. S. T.,et(1999) • Markings are used on rural 80km/h roads.

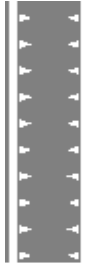
This is the example of a picture about Drenthe Province PCM which is installed in Netherlands as seen in figure 5.



Figure 5. Example of Drenthe Province PCM on the road

Dragon's teeth: as shape of dragon's teeth, these patterns are laid on the approaches to the gateways within villages. The gateways consisted of signing incorporating the 30mph speed limit, a speed camera warning sign, the village name and slogan 'Please drive carefully', on a yellow background)

Table 5. Summary of result for dragon's teeth

Country	Type	Summary
UK		<input type="checkbox"/> Department for Transport(2005) • Markings are laid on the approaches to the gateways

This is the example of a picture about dragon's teeth line which is installed in UK as seen in figure 6.







Figure 6. Example of Dragon's teeth on the road

## 2.3 PROPOSAL OF PERCEPTUAL TECHNIQUES






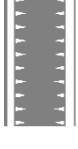
This study aims to Propose of Pavement Markings for Speed Reduction on the national highway curves. So a study tried to suggest some idea of the suitable pavement markings and determine which patterns are effective to reduce a speeding on the national highway curves. As mentioned above, each projects that had been done in abroad before was examined. The selected methods in this study considered the techniques which are only relative to speed reduction and excluded techniques used on intersections.

To sum up about proposed perceptual techniques for speed reduction on the national highway curves is as follows.

Table 6. Proposed techniques for national highway curves

Type		Country	Review for Application	Yes or No
Transverse Lines		UK	<ul style="list-style-type: none"> <li>Used on roundabouts, on the main carriageways.</li> <li>- Not used at sharp bends or other hazards.</li> </ul>	
		USA	<ul style="list-style-type: none"> <li>Used on major four-lane undivided highways.</li> </ul>	Yes
Peripheral Transverse Line		USA	<ul style="list-style-type: none"> <li>Used on two lane rural roadways for speed reduction.</li> </ul>	Yes



		Australia	<ul style="list-style-type: none"> <li>Designed to encourage drivers to decelerate rapidly when approaching to intersections.</li> <li>- However, this study requires gradual deceleration.</li> </ul>	
		USA	<ul style="list-style-type: none"> <li>Used for traffic calming on residential streets with posted speed limits of 25mph (or below)</li> </ul>	
Converging Chevron markings		Japan, USA	<ul style="list-style-type: none"> <li>Used on high-speed ramps.</li> </ul> <p>Guidelines in Japan and USA are the same. Technique in Japan is used in this study.</p>	Yes
		UK	<ul style="list-style-type: none"> <li>Intended to remind drivers to keep a safe distance from the vehicle in front.</li> <li>- Therefore this technique may not be suitable for road curves.</li> </ul>	
Drenthe Province PCM		Netherlands	<ul style="list-style-type: none"> <li>Used on rural 80km/h roads for speed reduction.</li> </ul>	Yes
Dragon's teeth		UK	<ul style="list-style-type: none"> <li>Laid on the approaches to the gateways within village for traffic calming.</li> <li>- So this technique can not be used on road curves.</li> </ul>	

### 3. DISCUSSION

This study will apply several pavement marking treatments conducted by foreign countries to this study. After conducting thorough research, it was concluded that perceptual countermeasures are likely to affect a driver's perception of speed on the road. These included Transverse Lines, Peripheral Transverse Lines, Converging Chevron markings, Drenthe Province PCM and Dragon's teeth. Further research will be required to determine which of the four pavement markings is most suitable for national highway curves.

Treatments used on roundabouts or areas within a village for traffic calming were excluded because of the possibility of encouraging drivers to reduce rapidly. For that reason, these techniques can be dangerous for reducing speeds on the national highway curves. But techniques used on the other sections of roads were accepted, because they encourage drivers to decelerate gradually. Therefore these techniques can be suitable to road for the national highway curves.

#### **4. FURTHER STUDY**

Firstly, a systematic study will determine effectiveness of these treatments in reducing travel speed on the roads in this study.

Secondly, due to concerns over drivers becoming too accustomed to implemented markings, the study determines the long-term effectiveness of these countermeasures.

Thirdly, the color contrasts (ex; a dark asphalt pavement with white marking) can be considered.

Lastly, techniques used on roundabouts or areas within a village for traffic calming like dragon's teeth and so on are needed to apply to road curves in order to see how drivers react in situations of rapid deceleration.

#### **5. ACKNOWLEDGMENTS**

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